In the matter of
United States Patent
Application no.
10/030,998

STATUTORY DECLARATION

I, Christopher Frederick Bayne, company director, of 6/15 Heremai Road, Henderson, Auckland, New Zealand, solemnly declare:

1.
I am the inventor of the invention disclosed in United States patent application no. 10/030,998 (hereinafter referred to as "my patent application").

2.
I am the managing director and principle shareholder of Paulmen Seals Limited (hereinafter referred to as "my company"), a company registered under the laws of New Zealand. Since I left school more than 25 years ago I have spent my entire working life working directly with mechanical seals, i.e. seals of the type with which my patent application is concerned.

a. In 1977 I got my first job in which I worked for three years as a tradesman, machinist and toolmaker for Rotary Seal, a company that manufactured mechanical seals in New Zealand. In that time I obtained the qualification of New Zealand Trade Certificate in Toolmaking.

b. From 1980 I spent two years setting up a manufacturing and service facility for Rotary Seal in Australia. In that time I was responsible for all aspects of the design and manufacture of the company's seals as well as for management of the facility in Australia.

c. In 1983, I set up a company, Bayne Bros. Pty. Ltd., in Australia. The business of this company was the reconditioning of pumps and seals used in a range of industries including the chemical and petrochemical industries, oil refineries, the food and beverage industry,

pulp and paper, marine, air-conditioning and refrigeration, power generation and mining industries, water and waste-water treatment plants, the steel industry and aluminium smelting. The company did work for these industries throughout Australia and also in Singapore, Malaysia and New Zealand. Manufacturing new seals for these industries was an integral part of the business of the company.

d. In 1986 the assets of Bayne Bros. Pty. Ltd. were bought by Sealing Devices Australia, a seal manufacturing company. Their stated purpose in doing so was specifically to obtain my expertise and expand their market share and to add pump reconditioning to their business activities. I worked for them for 2½ years.

e. In 1989 I re-established my own mechanical seal manufacturing company, Bayne Bros. Pty. Ltd., manufacturing and servicing mechanical seals in the same industries and countries as I have described above.

f. Initially we (i.e. Bayne Bros Pty Ltd.) purchased mechanical seal products from Paulmen Engineering Ltd in New Zealand, to complement our product range and meet demand. Within twelve months we became Paulmen Engineering Ltd's largest customer. At this point, in 1990, I successfully negotiated the acquisition of Paulmen Engineering Ltd. The company was re-named as Paulmen Seals Ltd - "my company" as noted above. From that time on, for the past 13 years, we have expanded the product range of mechanical seals. Apart from sales in New Zealand, my company exports mechanical seals to many geographical locations including Australia, Singapore, Malaysia, Thailand, Indonesia, U.S.A., Canada, Germany, Hong Kong and China.

3.

From the time that I bought it my company has manufactured and sold labyrinth-type mechanical seals. My patent application deals with seals of this type and in this declaration, the term "seals" will refer to labyrinth-type seals unless it is clear from the context that this is not intended. All of the seals produced by my company since I bought it have been designed wholly or in large part by me. I will use the term "new seals" to refer to seals that

and operation of any labyrinth-type seal.

5.

The new seals are designed for use in materials handling equipment of the type set out on the first page of the specification of my patent application. In all such equipment , there are significant quantities of particles entrained in the working media. I believe that it is worth paraphrasing here what is pointed out at lines 18-29, page of the specification as filed. That is, in labyrinth seals that are intended for use with liquid media, the conventional approach is to design the labyrinth passage so narrow that only a film of the liquid is present in the passage. This means that the designed passage width would certainly be less than the size of the entrained particles. For handling gaseous media, the conventional approach is to design the passage even narrower. The reason for this is that, in such equipment, particles of a range of sizes are always present in the gas. Some of these particles are considerably smaller than the nominal size of the particles for which the equipment is designed and the seals must be capable of excluding any such smaller particles where they occur in significant quantities. I attach hereto, as exhibit "A", copies of pages 411 to 413 of the "Seals and Sealing Handbook", the standard work of reference for seal designers worldwide. This material confirms that the conventional approach is to reduce the width of the passage as much as possible. I should add that very little material has been published that deals with seals for equipment for handling dry powders and other abrasive materials. Be that as it may, I am unaware of any conventional labyrinth seal intended for use in the kind of materials handling equipment that my patent application is concerned with, in which a substantial part of the passage has a designed width (when the seal is new) that is greater than the aforementioned expected particle size.

6.

I have carefully read US patent no. 4353559 in the name of Budzich as well as the other patents listed in the official action that has issued in connection with my patent application. At lines 16-21 on page 3 of the specification of my application as filed, it is pointed out that the seals that are conventionally used in applications where there is a substantial amount of abrasive material such as grit or dust in the working medium are not very satisfactory. At lines 25-34 of column 1, the Budzich patent confirms this. In any case I believe that this is

incorporate the improvements covered by my patent application.

4.a

I have thus had more than 23 years experience in the conception, design, manufacture, quality control, marketing and operation of seals. Throughout my working life, I have tended to focus on the more highly-engineered mechanical seals for complex applications rather than the low-end mass-produced variety. Complementarily, my company has concentrated on tackling the more difficult applications that other seal manufacturers historically avoid. Although this strategy has been for the purpose of gaining market share, I believe that the end result is that I and my company have developed considerable expertise in such applications. Furthermore I have developed and maintained a high level of awareness of the products and designs of all other recognised mechanical seal manufacturers.

4b.

I am on occasion called upon as a paid consultant to make recommendations and provide sealing solutions for various corporations. I also provide formal training for corporations' employees and engineers regarding the technical aspects of mechanical seal engineering. I have studied various technical books and other publications on seal design and operation and have made it my business to keep abreast with new developments in this field.

4c.

My company's manufacturing facility in Auckland, New Zealand enables us to cover every aspect of design and manufacture of special mechanical seals as well as our standard product range. Our in-house manufacturing facility produces all conventional designs of mechanical seals. e.g. single spring seals, multi-spring seals, welded metal bellows. These products cover all standard industry applications including vacuum to high pressure, cryogenic to high temperature, low speed to high speed, fluids, gases, slurry, and pulverulents. In addition to this, as far as I am aware, we are the only mechanical seal company in Australasia capable of producing spiral grooved and etched face dry-running gas seals in-house.

4d.

I thus believe that I am well qualified to pass opinions and make judgements on the design

notorious in the industry. In simple terms, conventional seals wear out quickly -- sometimes within two weeks, as suggested by Budzich, in the example of the equipment described in his patent. Such a short working life is in line with my experience of conventional seals in similar working conditions.

7.

Budzich does not make any attempt to reduce the rate of wear. It is evident that he accepts that the seal will wear out in the same time (as little as two weeks) as conventional seals fitted to the same equipment. Instead, his solution is to provide a seal that is quicker to fix when it is worn than is the case with conventional seals. This is a sound approach but does not involve any change to the design of the actual labyrinth passage. There is nothing in his patent that suggests that Budzich had in mind anything other than a passage of conventional design.

8.

Neither the Budzich patent nor any of the other references in the official action gives any quantified information as to the sizes of the components that define the labyrinth passage, or the clearance therebetween,. At line 61, column 1, Budzich does state that the faces defining the labyrinth passage are located "closely adjacent" each other. But, if it is accepted that the actual passage of Budzich's seal is of conventional design (as I have asserted in the preceding paragraph), then the term "closely adjacent" must imply that the faces are much more closely spaced than they are in the seals constructed according to my invention. This appears to be confirmed at column 3, lines 31-32, where it is stated that the passage (Budzich calls it an "opening") must be prevented from becoming large enough to allow material to come into contact with the bearings. As far as I can see, this can only mean that the passage is initially small enough to prevent the material from entering in the first place. Looked at another way, since there is no description or information about the actual dimensions of the labyrinth passage, experienced persons in the industry would take it for granted that Budzich's seal would be designed and constructed so that the faces are as closely spaced as possible.

The same reasoning can be applied to the other prior patents referred to in the official

action.

9.

It is trite to say that no seal has yet been designed that does not eventually wear out. Experienced people in the industry know that the primary reason for this is that the interfacing parts of the seal are degraded by abrasive particles entrained in the working medium that inevitably find their way between the parts. Granulators and other crushing machines are designed to reduce the material that they handle to a certain nominal particle size. However, as I have stated above, it is common knowledge that varying amounts of smaller size particles are produced in all such operations. This has certainly been my experience in every similar such operation that I have ever dealt with. These particles always include dust particles that are typically small enough to penetrate between the faces of the seal. The particles also include others that are of irregular shape and, although too large overall to enter the passage without hindrance, have some parts small enough to do so. Such particles may, for example, be flat or long and thin. Some of these get caught between the rotating faces and migrate into the passage, degrading the faces as they go. I stress that this size variation is common knowledge in the industry and I have no doubt that this is what Budzich had in mind in the statement at lines 17-32, column 3, referred to in the official action. The statement is essentially a paraphrase of what I have tried to explain above.

10.

In summary, I believe that neither Budzich nor any of the other prior patents referred to in the official action say anything about the actual labyrinth passage of a seal that is not likely to be already known to anyone who has had a reasonable amount of experience in either the design or use of such seals.

11.

The concept behind the new seals covered by my patent application is that the labyrinth passage is formed by layers of particles deposited on the opposed faces of the rotor and stator. These particles are of course derived from particles that are entrained in the medium in which the new seal will operate. To enable this to happen, it is necessary to substantially increase the clearance between the faces. In practice, I have found that this clearance is

considerably greater than twice the expected nominal size of the entrained particles. However, increasing the width of the passage would, by itself, make it easier for even larger entrained particles to enter and pass through the passage. This would therefore cause the new seal to be ineffective and/or to increase the rate of wear. To prevent this happening, it is necessary to provide some means of ensuring that there is no significant flow of liquid or gas (carrying entrained particles with it) into the passage until the particle layers have been formed. This is achieved in the first place by increasing the length of the passage to the extent that there is sufficient pressure gradient from one end of the passage to the other. It may also be assisted by providing sacrificial rings that initially act as seals until they wear out. I have however found that significantly increasing the passage length is often sufficient and it is not necessary to provide the sacrificial rings as well.

12.

For the first eight years after I bought my company, the labyrinth seals that we produced were conventional in the sense that I have described above, i.e. the passages were designed to be as narrow as working parameters allowed. We found that the seals that we produced during that time for crushers, hammer mills and the like did in fact encounter problems of the kind that I have discussed above with the result that the working life of our seals was limited and in any case no better on average than the seals of our competitors. I mulled over these problems for years, considering various ways of preventing entrained particles from getting into the passage. In the course of dismantling and examining seals that had failed, I often noticed that layers of fine particles build up on the faces of the passages of the seals. I also noticed that these layers are often quite stable. I have no doubt that it has been well known for a long time that such layers build up on any surface (including the surfaces of a seal) of equipment that is exposed to the working medium. I should stress however that at that time I did not attach any significance to these observations. In fact, if anything, I took an adverse view as, in common with other maintenance people in the industry, I tended to see such deposits as the cause of failure of the seal in question. In line with conventional thinking, at the time I looked for ways of stopping the dust from getting into the passage and took it for granted that, for this purpose, the labyrinth passage of a seal should be as narrow as possible. But eventually I started to wonder whether it would be possible to use these layers to create the passage. I cannot now recall when this idea first occurred to me but it

was in any case some years before I did anything about it. This was because, for a long time after first thinking about it, I was very doubtful that such a seal could be made or that it would work. In the first place, I could not see how to design a seal in which the layers would form before the particles destroyed the seal through wear at a faster rate than ordinary seals. It was not at all obvious to widen the passage. It seemed self evident that this would allow even more particles to get into the passage and therefore lead to even more rapid destruction of the seal through wear. Furthermore, it was not at all clear that the layers would actually build up in such a way as to create a functional passage. And it was also not certain that the layers would be strong enough.

13.

Even at that stage I realised that one precondition to enable the layers to form would be that the passage would have to be substantially wider than the particle size so that particles deposited on one surface would not be knocked off by particles deposited on the other surface and also so that additional particles could migrate between the layers after they started to form. And I also realised that there would have to be no significant flow of particles through the passage. To achieve this I initially thought of using a sacrificial sealing ring but I had rejected this as I had no idea, assuming that the layers did in fact start to build up, how long it would take for them to do so and whether the ring would last long to allow this to happen. Eventually I concluded that increasing the length of the passage substantially (to compensate for the increase in width) might achieve the desired result.

By this time, finding a viable sealing solution for dry powder had become somewhat of an obsession to me. At times I was thinking about various approaches both day and night, awake and asleep.

When thinking about the extremes of wear resistance, I considered diamonds and that only diamonds cut diamonds and that perhaps various products in particle form would tend to provide good wear resistance from themselves

With regards to any mechanical applications, product compatibility is also a priority and in part from this I concluded that if one could use the product to seal the product, material incompatibilities may also be overcome.

14.

I repeat that, in the face of all these uncertainties, although optimistic, I was by no means certain that the seal would work. Nevertheless, in 1993 I constructed an initial test seal that by design incorporated a wider and longer passage and was much surprised and pleased to find that it did work.

15.

From that time (1993) to the time that we lodged our New Zealand patent application no. 336765 in July 1999, we produced at least a further six of the new seals for testing purposes. For this purpose I invested considerable funds and time into constructing several purpose built in-house test rigs of various types. During these testing processes, I used a multitude of products in powder form, some of which included: Iron Sand, Sand, Silicate, Aluminum Oxide, Flour, Wheat, Grain, Milk Powder, Sugar, Caster Sugar, Icing Sugar, Cement Powder, Iron Filings, Stones/Gravel, Cocoa Powder, Sulfur and Lime.
Despite this rather long period trial and experiment, even today it is not clear to me how, in the new seals, the layers are able to build up successfully to form a labyrinth passage and I am still conducting research. After all, as a conventional seal wears, the width of its passage increases and you would think that the layers would eventually build up on the worn surfaces and form a labyrinth passage. But this has never happened in my experience. Worn conventional seals do not "fix" themselves in this way, probably due to the fact that the passage of a conventional seal is not long enough to prevent the flow of fluid through it when it becomes enlarged through wear.

16.

It takes a variable but surprisingly short amount of time after the new seals are installed for the thickness of the deposited layers to build up to the point where they are so close together that the width of the passage that they create is as narrow as the passages in conventional labyrinth seals. This time varies, depending on the nature of the material being handled, amongst other things. For example, both aluminium oxide and flour have the well-known property that their particles tend to bond together, so that the layers of these materials are formed in a matter of hours. The layers of many of the other materials handled by equipment of the type in which the new seals are used could be expected to form in a day.

17.

Whatever the position, from the time that we first introduced them, the working life of our new seals has been dramatically greater than that of conventional seals used in the same applications up to that time. Since my company started to market the new seals in 1999, we have sold about 200 and we have come to routinely expect that the life of the new seals when used in the same equipment to replace conventional seals will be of the order of years. In many cases, in discussions with customers before our new seals were installed, many of them have reported that they expect the life of conventional seals to be of the order of weeks or months, in some cases even days, in line with the statement in the Budzich patent referred to above, and with my own experience. In the nature of things, such reports unfortunately tend to be verbal. But, for example, one of the first of the new seals that we produced was sold in 1999, for use in a sugar mill. It is still in place. I recall that I was told by the representative of Sunshine Sugar (the company that bought the seal) that the conventional seals that they were using at the time were lasting about three days. I particularly remember this case because it was one the first of the new seals that my company produced. However, I would not now regard this case as exceptional.

18.

As far as I am aware none of our new seals has failed prematurely. Although in some cases they have been replaced, there has been no failure prior to programmed shut down of the plant in question for the purposes of routine preventive maintenance.

19.

We are now so confident of the performance of the new seals that we are prepared to offer a one-year warrantee on them. This warrantee is subject to the condition that we must be satisfied that the customer has an adequate preventive maintenance regime. I am confident that we could design a new seal for use in a granulator for chopping wire or cable of the type for which the example seal in Budzich's patent is evidently intended and that we could safely offer an equivalent warrantee.

And I make this statutory declaration conscientiously believing the same to be true and by virtue of the Oaths and Declarations Act of 1957.

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Christopher Frederick Bayne

Declared at Auckland this 14th day of April, 2003, before me, a solicitor of the High Court of New Zealand

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Stephen Geoffrey Dye
Solicitor
AUCKLAND

FROM :PAULMEN SEALS LTD FAX NO. :64 9 838 9346 Mar. 14 2003 05:20PM P7

LABYRINTH SEALS

Labyrinth seals operate with positive clearance and provide sealing by virtue of a lengthy, tortuous gap path. Sealing then depends on the form of the labyrinth gap and the length of the leakage path. The basic labyrinth form can be provided by rings on the shaft and grooves in the housing (Figure 1), but more efficient forms are alternating teeth or alternating serrations (Figure 2). Tapered teeth are generally considered to be more effective in reducing leakage to a minimum with a given clearance and seal length, particularly when sealing gases.

The efficiency of a labyrinth seal increases in inverse proportion to the clearance gap, thus the smaller the gap the better, provided contact can be avoided within the seal under running conditions. The gap has to be larger than the axial or radial clearance on rolling bearings carrying the shaft, for example, or greater than the elastic deformation which may occur on anti-friction bearings. Typical assembly fits with anti-friction bearings are Housing: ISO K7, M7 and N7; Shaft: ISO h6, j6 or k6. The effect of thermal expansion closing the gap at operating temperatures must also be taken into account in determining a suitable gap.

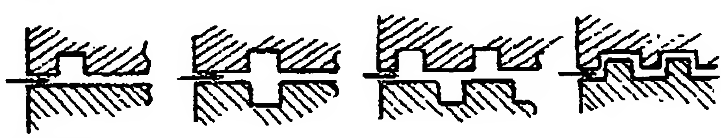


FIGURE 1

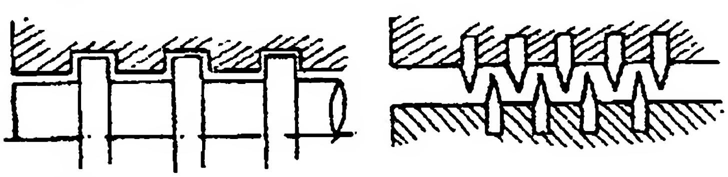


FIGURE 2

FROM :PAULMEN SEALS LTD FAX NO. :64 9 838 9346 Mar. 14 2003 05:21PM P8

Alternatively, where there is a distinct possibility of contact occurring within the seal the teeth may be made of a material which sublimates rather than melts, so that, in the event of contact, galling or scoring of the mating member is avoided. Another solution is the use of carbon for one set of teeth where the effect of occasional rubbing contact will be minimal. (More prolonged rubbing contact would run-in the carbon face(s) to a light 'bearing' fit).

Typical forms of proprietary labyrinth seals are shown in Figure 3. Both comprise an outer housing ring and an inner shaft ring formed with matching tooth profiles to operate with positive clearance. The second seal also has a number of peripheral slits through which any droplets of liquids which penetrate the seal are ejected under centrifugal force and then flow out through an annular groove with a drain hole in the housing. This is a preferred design where heavy splashing can occur.

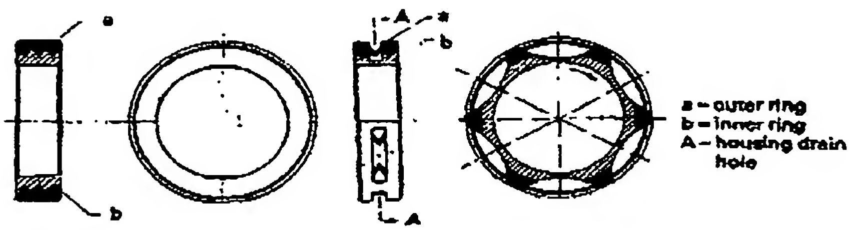


FIGURE 3
Proprietary labyrinth seals

A further form of labyrinth seal is shown in Figure 4. Here the gap takes the form of a zig-zag, the seal being aligned so that the larger labyrinth diameter faces the fluid being sealed. Once fluid has entered the gap centrifugal force, assisted by the shape of the teeth, promotes a blocking action in the convergent leakage path, promoting better sealing. This is particularly effective when the fluid is a gas. Where the fluid being sealed is a liquid, performance can be improved by incorporating a discharge port in the inner or outer ring to reduce pressure build-up through the clearance path (Figure 5). This port must always be located at the bottom of the ring.

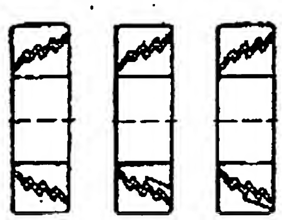


FIGURE 4

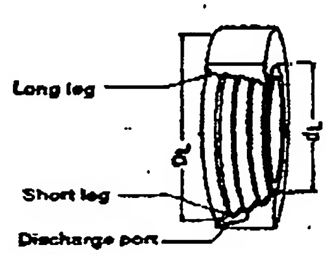
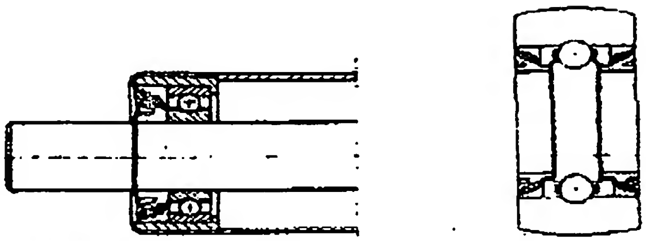


FIGURE 5



Single- and double-labyrinth seals for grease-lubricated ball-bearings

Other variations on the simple labyrinth seal include the use of teeth set at an angle or with different pitch angles on rotating and stationary members so that a back-pumping effect is produced (ie the seal is given wind-back action and works as a positive action hydrodynamic seal).

Labyrinth seals are used quite widely as seals for rolling bearings, as well as for sealing shafts and spindles on heavy industrial machinery and other applications where relatively large leakage rates can be tolerated and a simple seal is required. Being *non-contact* seals they do not generate friction or heat and, with properly selected clearances, are suitable for high temperature services.

A further type of seal operating on pure labyrinth principles is the metal honeycomb ring working with light rubbing contact. In this case the labyrinth path is provided by the honeycomb structure. Seals of this type using a stainless steel or similar honeycomb are strong enough to resist erosion and degradation under pressure in such applications as *tip* seals for rotors.

See also chapter on *Carbon Seals*.

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